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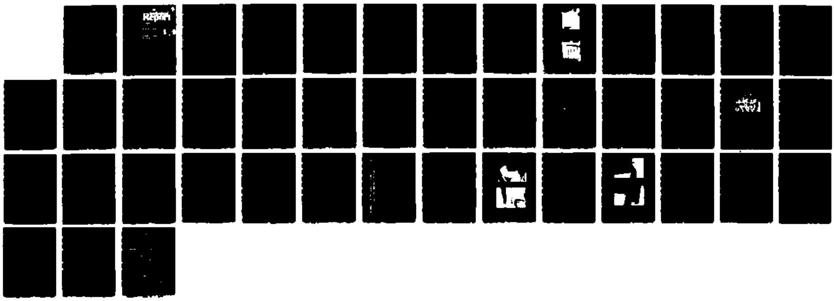

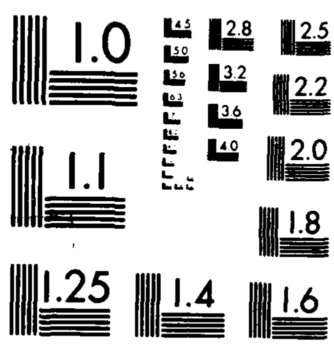
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technical Report

United States Army
Belvoir Research, Development & Engineering Center
Fort Belvoir, Virginia 22060-5606

REPORT 2456

LACV-30
Auxiliary Power Unit
Air Filter

Authored By: James A. Yescavage
Jonathan D. Ives

Report Date: January 1988

Unclassified

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James A. Yescavage and Jonathan D. Ives

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This technical report presents Belvoir RD&E Center analysis of and proposed solution to problems (severe clogging, fire hazards, high replacement costs, maintenance requirements) caused by paper air filters on the gas turbine Auxiliary Power Unit (APU) on the LACV-30. The proposed LACV-30 replacement filters have three stages of cleaning: an inertial separator, a mist eliminator pad, and a foreign object damage (FOD) screen. The new filter decreases the need for spare parts and extensive maintenance, extends the life and efficiency of the APU, and increases horsepower by 3%. This report contains the contractor's (Pall Corporation) Technical Proposal and Field Performance Study.

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PREFACE

Testing of replacement filters was conducted during May and June 1986 at Fort Story, Virginia, to determine if these filters provided an acceptable solution to problems caused by paper air filters on the gas turbine Auxiliary Power Unit (APU). The problem areas included severe clogging, fire hazards, high replacement costs, and maintenance requirements.

The LACV-30 replacement filter has three stages of cleaning:

1. An inertial separator;

2. A mist eliminator pad; and

3. A foreign object damage (FOD) screen.

This clean, reusable filter system decreases the need for spare parts and extensive maintenance, extends the life and efficiency of the APU, and increases horsepower by 3 percent.

This report includes the original technical proposal of the LACV-30 filter (Appendix A), and documented testing procedures and results (Appendix B).

CONTENTS

SECTION I. BACKGROUND

The Lighter, Air Cushion Vehicle, 30-ton (LACV-30) is a high-speed aircraft capable of carrying 30 tons of cargo over water, land, ice, and marginal terrain. The primary mission of the LACV-30 for the US Army is the transport of containerized and wheeled cargo from supply ship to shoreside marshalling areas in support of logistics over-the-shore (LOTS) operations. The LACV-30 can also be used in such missions as ice breaking, search and rescue, and other coastal, harbor, and inland waterway roles.

It is the purpose of this report to outline problems with the existing paper barrier air filter for the LACV-30 Auxiliary Power Unit (APU) and to present recommendations for its replacement. The principles of air cushion vehicle operations, couples with theamphibious nature of the LACV-30's mission, subjects the air intake system to excessive ingestion of sand and salt water mist. This necessitates a reliable air cleaning system to protect the five gas turbine engines which power the LACV-30.

The LACV-30 is powered by four (i.e. two twin pack) Pratt & Whitney ST-6 turbine engines. The Auxiliary Power Unit (APU) is an Alturdyne/Solar "Titan" gas turbine rated at 140 horsepower at 3,600 shaft rpm.

The air intake system for the four main propulsion engines and the APU was originally configured to pass all air through two Donaldson centrifugal separator type air cleaners. A portion of the cleaned air was diverted to the APU through about 12 feet of duct and a battery box to the plenum which was fitted with a barrier filter (Donaldson P/N P14-2243, with paper filter medium) as a final protection for the APU turbine against particulate contamination.

The problem with the original system was that the barrier filter in the plenum of the APU clogged after 5 to 15 hours of normal operation. Once the filter became clogged, the engine drew in hot exhaust gas, thereby creating a fire hazard in the APU.

SECTION II. ANALYSIS

In light of the high cost of replacement and fragile nature of the paper type air filter, in addition to the fire hazard it produces, an interim filter—a 140 microns stainless steel screen—was used on the LACV-30 until a permanent solution could be achieved. However, the interim filter does not provide the long-term protection which the gas turbine APU requires.

It was proposed by Pall Land and Marine Corporation, a subsidiary of Pall Corporation, that a Permakleen^{TM} Air Cleaner System to be utilized as a solution to the problems at hand. This system includes a mist eliminator which will aid in the removal of salt mist. This is necessary since inertial type precleaners are not effective in separating mist. The mist eliminator is shown in Figure 1, and the inertial separator in Figure 2. Appendix A contains the technical proposal for this system and details the advantages of the Permakleen^{TM} system over the original system. (For a schematic of this system, see Appendix A, page A-8).

It was decided to install the Permakleen^{TM} system on LACV-30-01 as a prototype to determine the feasibility of installation and to enable testing of the system under operating conditions. Evaluation of the new system was conducted by Pall Corporation Scientific and Laboratory Services Department. An isokinetic sampling device was used to capture particles in an ultraclean fluid using the principle of high velocity impingement at the inlet and outlet of the Permakleen^{TM} system under both land and ocean/beach operating conditions. Particles captured in the fluid were counted, and a sodium analysis was also conducted on the oil in the impingers to estimate ingression of sea salt during the ocean/beach run. A complete report (written by Pall Corporation) of the field performance study conducted is provided in Appendix B.

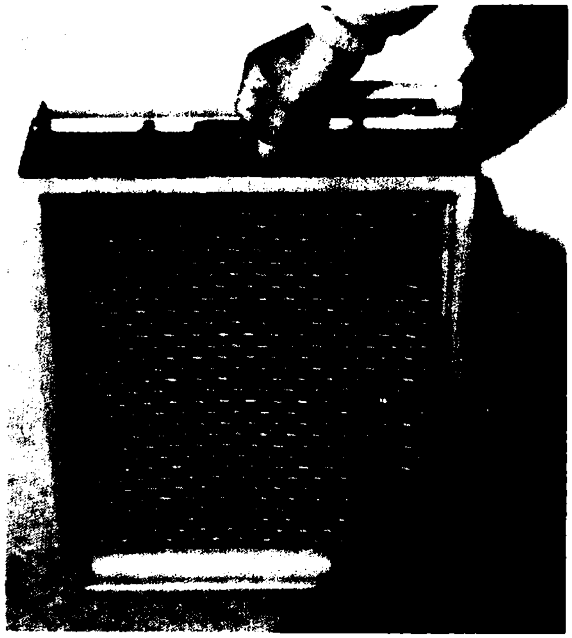


Figure 1.

Figure 2.

SECTION III. RESULTS AND CONCLUSIONS

The number of particles per cubic foot of air was calculated from the particle counting analysis in the inlet and outlet impingers. Based on these results, the Permakleen™ air cleaner was filtering more than 99.9 percent of the solid particles greater than 10 microns introduced at inlet operating over land.

Concerning the ocean/beach run, analysis of the oil samples for total sodium content shows that levels were reduced about 2.65 times from the air inlet to the system. Based on the average level of sodium in sea water, this equates to a 0.07 milliliter of sea water taken in by the APU turbine per cubic foot of air.

Due to the problems with the original air filtering system and the fact that the interim does not meet the protection requirements of the gas turbines, a new air filtering system is necessary and should be obtained and installed before time consuming and costly damage to the turbines is incurred. The Permakleen™ Air Cleaner System is one system meeting the turbine requirements and could be utilized.

APPENDIX A

TECHNICAL PROPOSAL

PERMAKLEEN ™

INLET AIR CLEANER SYSTEM

FOR

LACV-30 APU

P/N CJ-00125-1

LOG NO. 012902

CHARLES ROACH

CEDRIC SUN

APRIL 27, 1984

PALL LAND AND MARINE CORP.

PALL

A SUBSIDIARY OF PALL CORPORATION

7070 MOON LAKE ROAD • NEW PORT RICHEY, FL 33552 • (813) 849-9999

PLMS-8

PALL LAND AND MARINE CORPORATION
East Hills, New York

April 27, 1984

TABLE OF CONTENTS

1.0 INTRODUCTION AND SUMMARY

Pall Land and Marine Corporation (PLM), a subsidiary of Pall Corporation, hereby submits its unsolicited proposal for an extended service life air filter and salt mist eliminator system to overcome the LACV-30 APU inlet air filtration problems.

The proposed PermaKleen™ Air Cleaner System is an unitized assembly consisting of a self-cleaning inertial precleaner in series with a stainless steel recleanable depth type filter/demister element offering:

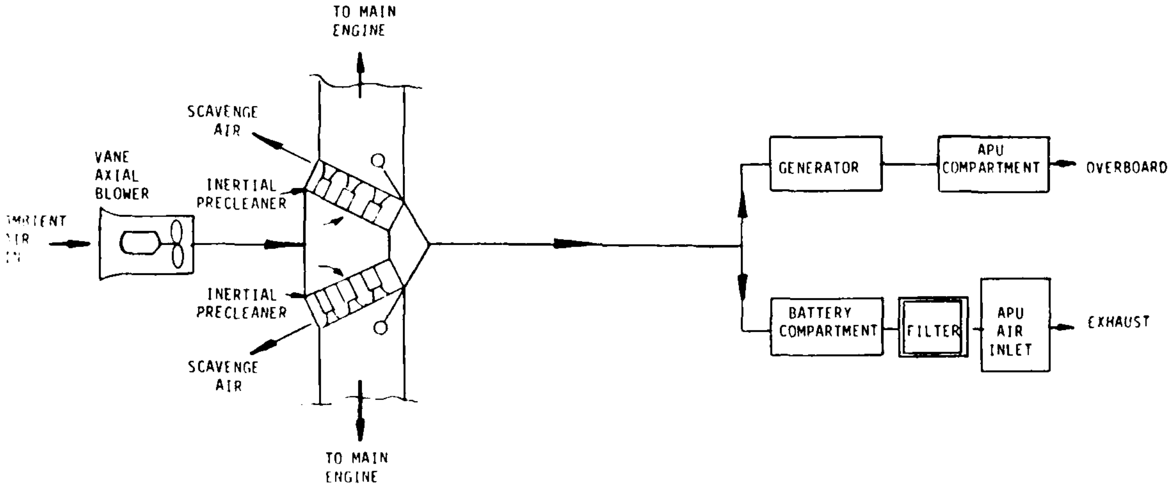
- Extended service life
- Salt mist removal
- Handles moisture laden air with no pressure rise
- Filter/demister element is easily cleanable and resistant to handling damage

The PermaKleen™ System can be retrofitted with minimal changes.

2.0 SYSTEMS DESCRIPTION

2.1 Present System

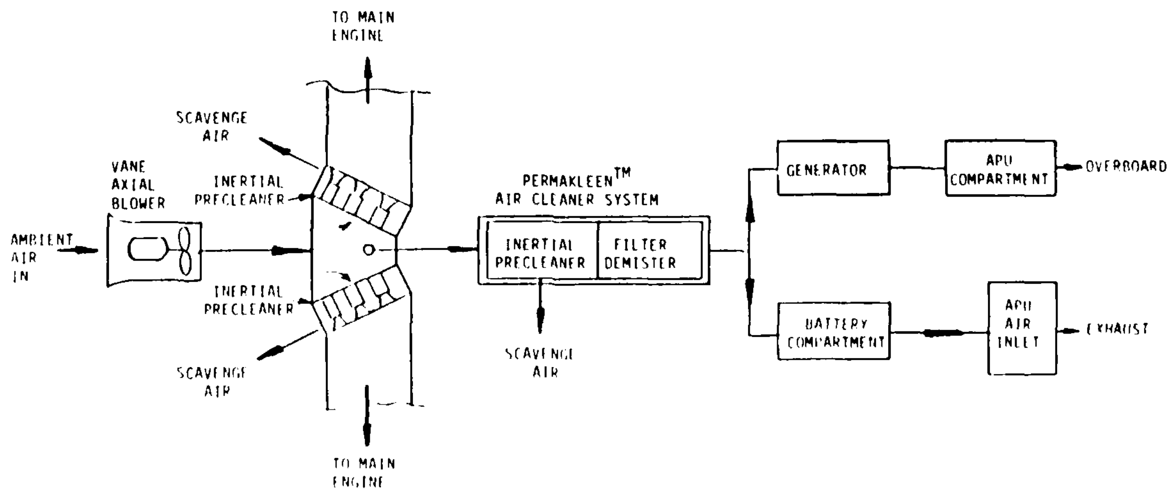
Figure 1 is a diagram of the current air flow into the APU. Filter is a cylindrical pleated paper element.



PRESENT SYSTEM
FIGURE 1

2.2 Proposed System

Figure 2 represents proposed PermaKleen™ Air Cleaner System.



PROPOSED PERMAKLEEN™ AIR CLEANER SYSTEM
FIGURE 2

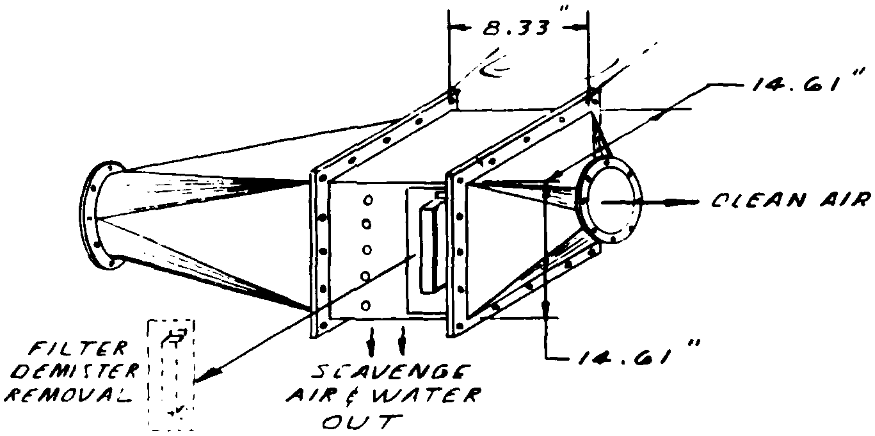
3. Pleated cellulose paper barrier filters have relatively short service life. Further, wet or moisture laden air can cause high flow restriction even in a clean filter element.

4. Paper filters are easily damaged during cleaning and servicing.

3.2 Proposed PermaKleen™ Air Cleaner Assembly

We propose our PermaKleen System; an unitized assembly replacing the current "shared" pre-cleaner and paper barrier filter.

Key components of this assembly consist of a dedicated self-cleaning precleaner and a field cleanable depth filter/demister element (see also Figure 7, Page 8).



PERMAKLEEN ™ AIR CLEANER ASSEMBLY
FIGURE 4

Please refer to enclosed proposal Drawing No. CJ-00125-1 for detail dimensions and performance values. Proposed configuration assumes a minimum of 8 inches water column static head is available at the precleaner inlet.

Separation efficiency and overall air flow resistance will be comparable to the existing system. Primary advantages over the present system are:

- Three to eleven times service life.
- Salt mist removal down to 2 microns.
- Provides filtered and demisted air to generator and compartments.
- No flow resistance increase in presence of wet or moisture laden air.

We propose to locate the air cleaner assembly beneath the inlet elbow of the vane axial blower; with the following modifications:

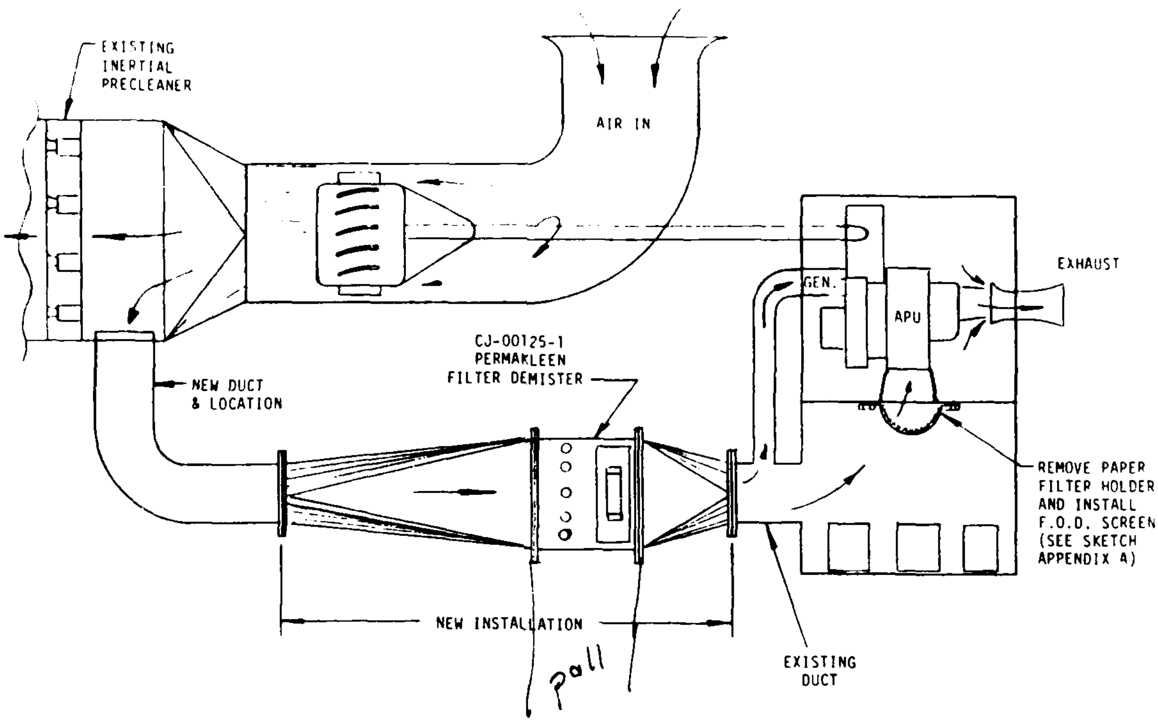
1. Remove the air duct (Y Section) leading from the main engine precleaners up to approximately one foot from the APU compartment inlet. Blank off the two precleaner discharge ports.

2. Place the air cleaner assembly below the vane axial blower elbow parallel with its flow axis.

3. Fabricate a new duct connecting from a point at the vane axial blower discharge plenum to the air cleaner assembly inlet. Connect the outlet to the APU compartment inlet duct.

4. Remove the paper barrier filter and holder bracket. Enlarge the APU inlet plenum opening to maximum dimensions and install a f.o.d. screen. (See Sketch Appendix A.)

Figure 5 depicts the PermaKleen System in place.



PERMAKLEEN ™ SYSTEM INSTALLATION
FIGURE 5

4.0 PERMAKLEEN AIR CLEANER SYSTEM

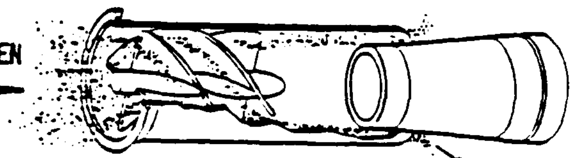
The proposed Permakleen Air Cleaner System is represented by the enclosed proposal Drawing No. CJ-00125-1. It is an unitized assembly consisting of:

1. Rectangular housing with appropriate inlet and outlet transitions to round ducting.

2. Within the housing is a permanently fixed multitube precleaner and a removable filter/demister element. The latter slides out for cleaning.

4.1 Precleaner

The precleaner is a flat panel made up of an array of precleaner tubes.

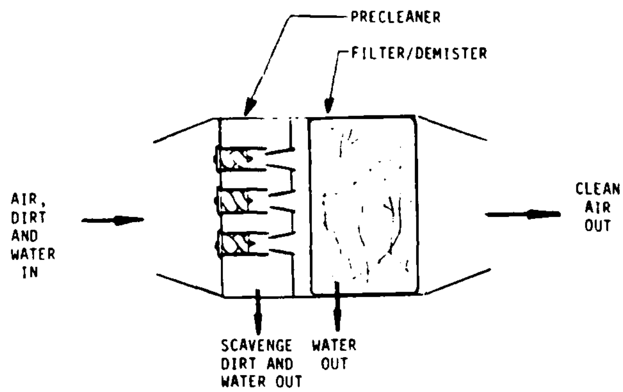


PRECLEANER TUBE
FIGURE 6

Dust and moisture laden air entering the precleaner tube is imparted a swirling motion induced by the vortex generator. This swirling motion causes dirt particles and water droplets to be centrifuged toward the wall of the tube. They are then scavenged overboard with a small portion of the inlet air. In a pressurized system, scavenge flow rate is controlled by discharge orifices in the housing. Cleansed air located within center of the vortex proceeds through the outlet.

Design of the precleaner is same as PLM's self-cleaning Centrisep Air Cleaners used to protect helicopter turbine engine inlet air. It was first installed on Army's OH-58 "KIOWA" Helicopter. This was followed by other helicopter models working in severe dust environments. Please refer to enclosure 1 titled "Centrisep Air Cleaner Systems" for background information.

The precleaner has a gravimetric dust separation efficiency of 92% (AC Coarse Test Dust). This is approximately equivalent to particle size cut off at 25 microns. It by itself, will not adequately protect a gas turbine operating predominantly in highly contaminated environments. Therefore, a filter/demister element is placed downstream (see Figure 7) to capture fine dust particles and salt spray mist down to 2 microns.



PERMAKLEEN™ AIR CLEANER SYSTEM
FIGURE 7

4.2 Filter/Demister

The filter/demister hereafter referred to as the "element" is a 4.5 inch thick panel made up. of looped stainless steel wire filament matrix. An oil film of MIL-L-23699 or equivalent covers the filter filaments.

Fine dirt particles are collected on the filament surfaces. Most of the dirt is collected within the first 2 to 3 inches of element depth. When filament surfaces are saturated, design pressure drop is reached. The panel should be removed for cleaning.

Unlike paper barrier type filters whose media are typically less than 0.020" thick, the filter/demister element is 4.5" thick. It cannot be easily punctured during cleaning and servicing. For example, pushing a nail into the panel has no appreciable effect on dust collection efficiency.

Salt spray mist impact and agglomerate on the wire filament matrix. Water is drained off. Under low humidity conditions, water evaporates leaving salt behind.

4.3 Separation Efficiencies

Overall separation efficiency of the PermaKleen Air Cleaner System is 99% (AC Coarse Test Dust). This compares favorably with 98.8% of the present paper barrier filter. The latter efficiency was based on our test of a pleated paper element removed from a vehicle at Fort Story. A separate laboratory report will be submitted.

The PermaKleen System is a good demister. A precleaner and 4" thick element was tested at the Naval Air Propulsion Center in 1980, using synthetic sea water per MIL-E-5009C. Test conditions unitized input concentrations of approximately 0.1, 1, 10, and 100 ppm salt-to-air ratio by weight for three relative humidity ranges. Salt removal was effective down to 2 microns.

A very severe simulated laboratory salt spray test was run by Shin Meiwa Industry, LTD. of Japan. It was performed on a system with a 2" thick filter/demister panel (as compared to 4.5" proposed). Based on the results, our system is now on board the PS-1/US-1 Flying Boat protecting the onboard AiResearch Garrett gas turbine APU. Copy of this report Publication No. APM-138 is enclosed (Enclosure 2). Two illustrations of airborne systems protecting gas turbines are shown in Enclosures 3 and 4.

4.4 Cleanability

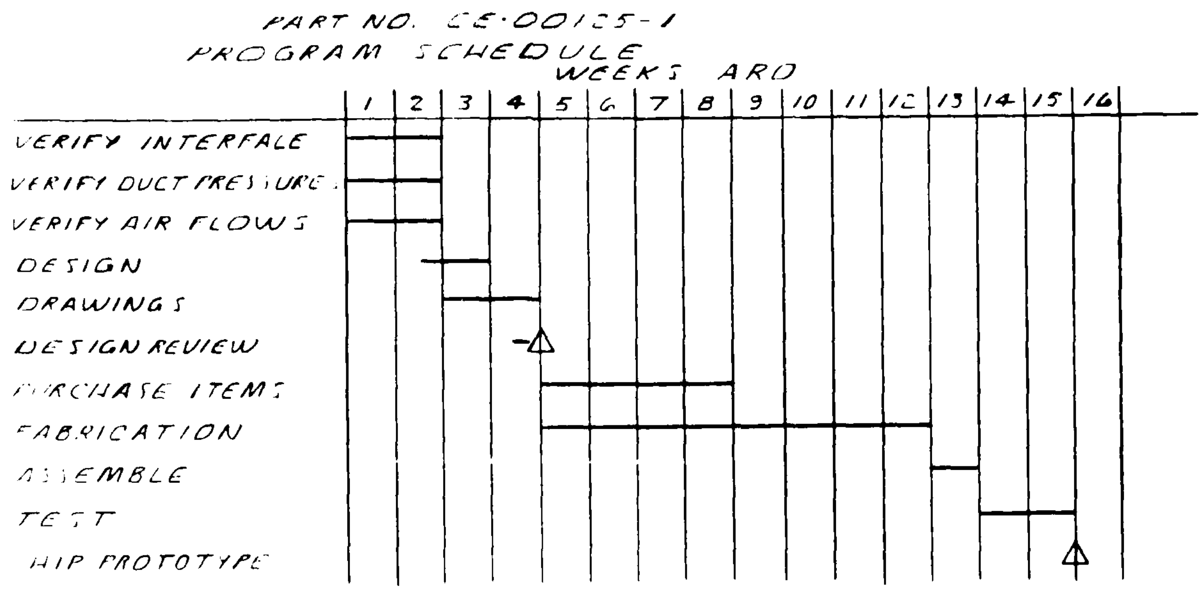
The precleaner panel can be cleaned by hosing with water from both the front and back faces. Loose dirt and salt water trapped within the panel will self-purge on next start up.

The filter/demister element can be readily cleaned by hosing with water and detergent. This to be followed by spraying with engine lubricating oil MIL-L-23699 or equivalent.

5.0 PROGRAM SCHEDULE

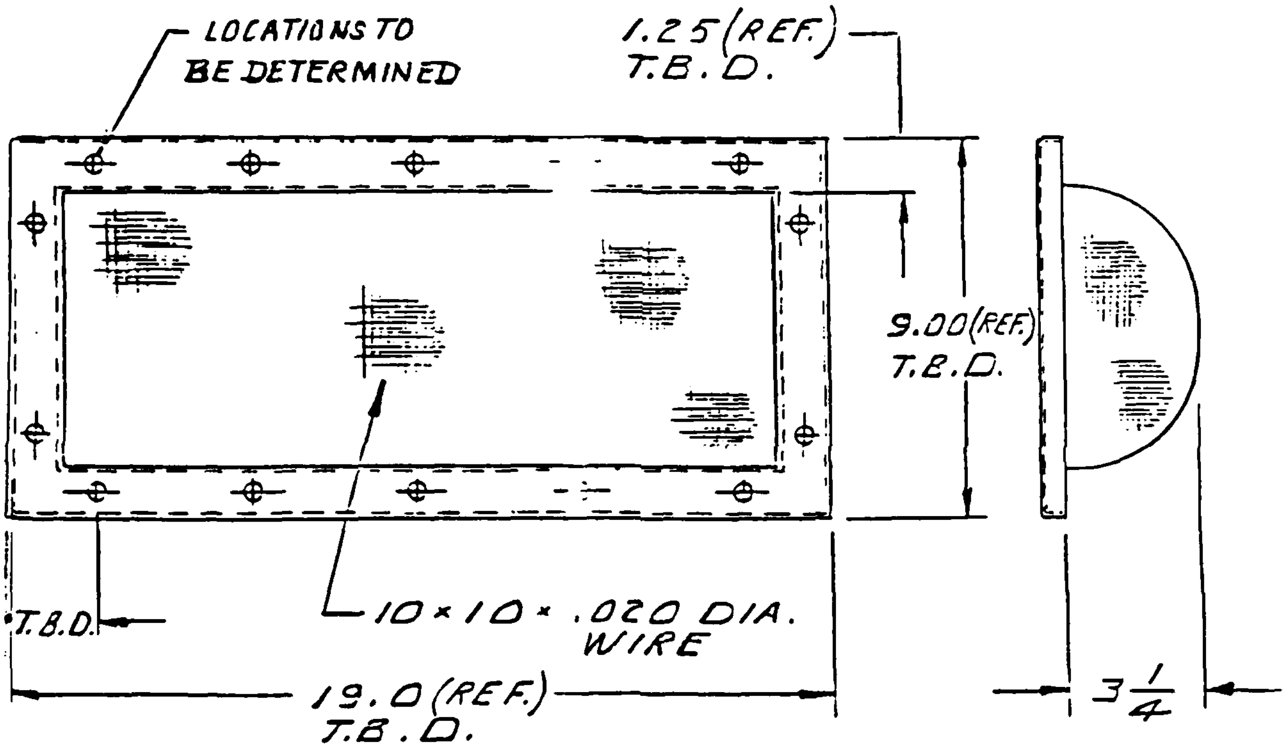
Design parameters and hardware configuration for this proposal were based on verbal inputs and onsite observations. They need to be confirmed. It can also be obtained by making field measurements on an operating vehicle. Milestone Chart below assumes all data for firm design is made available.

PROGRAM SCHEDULE



Pricing will be submitted separately.

A copy of Pall Corporation Annual Report is enclosed (Enclosure 5). Specific references to PLM are shown on Pages 19 to 21.


LOCATIONS TO BE DETERMINED
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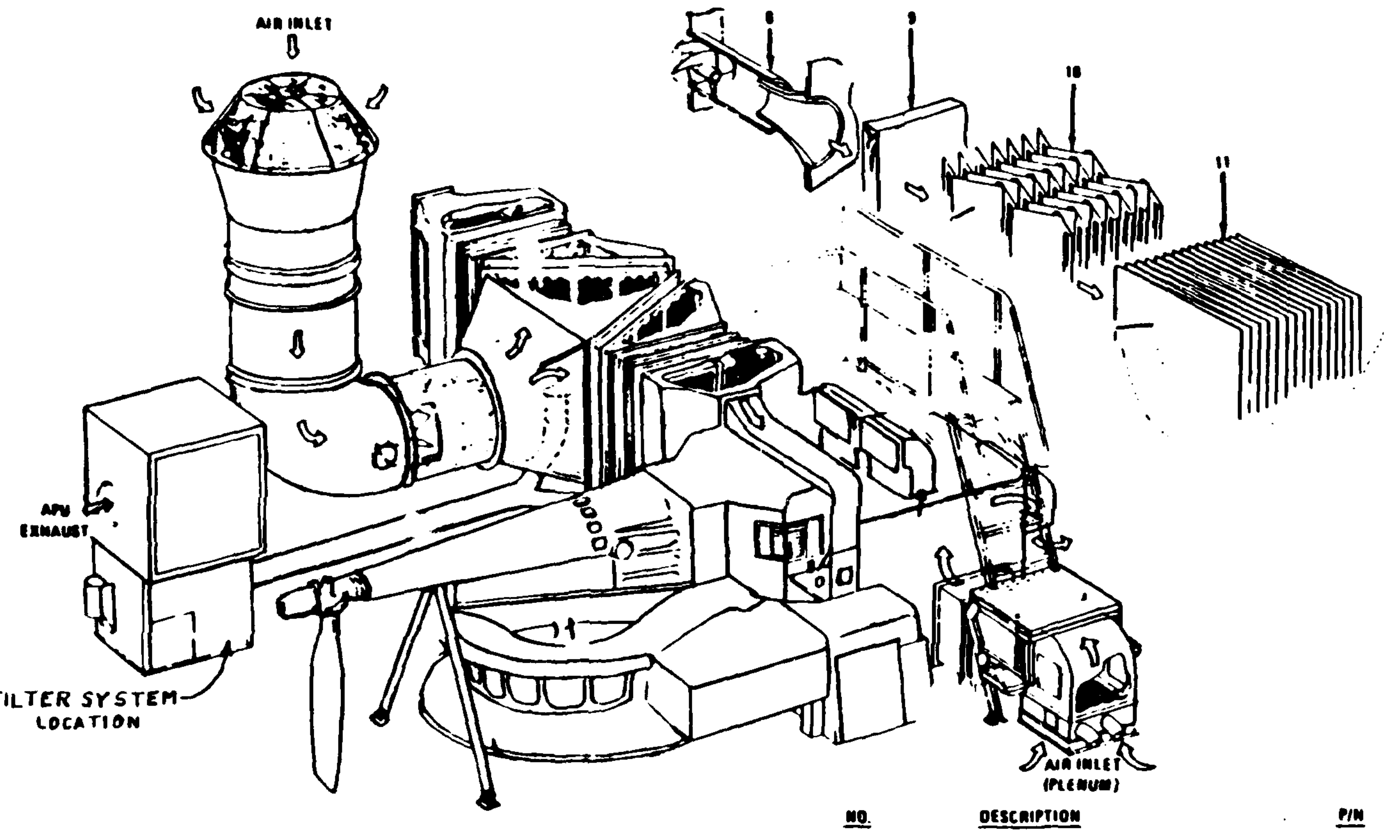
19.0 (REF.) T.B.D.
3 1/4

F. O. D. SCREEN



AIR MANAGEMENT SYSTEM INSTALLATION 4-420001

NO.	DESCRIPTION	P/N
1.	AUXILIARY POWER UNIT	T62 32 (SOLAR)
2.	FAN AND APU INSTALLATION	4 420002
3.	AJUSTAX FAN	MODEL 29 89 TYPE S (BUFFALO FORGE)
4.	DUCT ASSY (FILTER TO POWER MODULE)	4 420090
5.	PLENUM ASSEMBLY	4 420003
6.	SHUTTER INSTALLATION	4 420120
7.	DUCT-FILTER TO FILTER	4 420089
8	AIR CLEANER	6179R1066 (DONALDSON)
9	AGGLOMERATOR ASSEMBLY	-
10	MIST EXTRACTOR REF MODIFICATION	4B 73324 (PEERLESS) 4 420126

NO.	DESCRIPTION	P/N
11	BARRIER FILTER	P12-506 (DONALDSON)
12.	REF MODIFICATION TO INLET POWER MODULE	4-420105
14	REF MODIFICATION STEP WALK AND LADDER	2-160053
15.	OUTER DUCT	2-181052
16.	FILTER	2-181055 (DONALDSON)
17.	WIRE MESH SCREEN (BELOW DECK)	2-181051
18.	FLEXIBLE SLEEVE	2-181054
19	INNER DUCT DUCT AFT	2-181053
22	DIFFUSER INSTALLATION-FAN EXIT	4-420110

Figure 2-9-1. Air Management System

APPENDIX B

Pall Corporation

30 Sea Cliff Avenue · Glen Cove, N.Y. 11542 · USA
Phone 516-671-4000 · TWX 510 223 0606
Telex 126329 · Cable Pallco Glen Cove

SCIENTIFIC & LABORATORY SERVICES DEPT.
Director: Erwin Kirnbauer
FILTER PERFORMANCE TESTS
PROCESS & SYSTEM CONTAMINATION CONTROL
PARTICULATE & MICROBIAL FLUID CONTAMINATION ANALYSIS
WEAR ANALYSIS
BIOLOGICAL CONTROLS

August 6, 1986

SLS Report #1787

Revision A

A Field Performance Study of a PLM Permakleen™ Air Cleaner System Serving the APU of an LACV-30 for the U.S. Army, Fort Belvoir, Virginia (Rev. A)

Purpose

This study was conducted at the request of the U.S. Army to determine levels of particulate and sea salt contamination in the air stream at the inlet and outlet of the PLM Permakleen™ Air Cleaner System during operation of the LACV-30 over land and over ocean/beach at Fort Story, Virginia. (Rev. A)

Summary

An isokinetic sampling device was used to capture particles in an ultraclean fluid using the principle of high velocity impingement. Particles captured in the fluid were counted. Sodium analysis was also conducted on the oil in the impingers to estimate ingression of sea salt during the ocean/beach run.

Owing to expected variations in conditions during sampling in the field the results of analysis reported here are relied on only to show approximate levels and gross differences in the particulate/sea salt levels at the inlet and outlet of the PLM Permakleen™ Air Cleaner System.

The results of analysis show that the Permakleen™ Air Cleaner System is performing properly to remove greater than 99.9% of particles ingressing into the air intake system of the auxiliary power unit (APU) turbine.

Sea salt ingression levels were low (∿0.2 milliliters sea water equivalent/ft^3) at the system inlet. These levels were found to be about 2.65 times lower at the outlet of the Permakleen™ system (∿0.07 milliliters sea water equivalent/ft^3).

Based on the performance of the Permakleen™ Air Cleaner System it is recommended that this system be implementated on all LACV-30 craft as the air intake filtration system for the APU.

International Offices & Plants Pall Europe Ltd., Portsmouth, Pall GmbH, Frankfurt, Pall France SA, Paris, Pall Italia S.R.L., Milan
Pall (Canada) Ltd., Ontario, Pall Far East Corp., Tokyo, Marusho Ltd., Tokyo

Background

The LACV-30 is a Light Amphibious (Air Cushion Vehicle commissioned by the U.S. Army. The LACV is powered by four (i.e. two twin pack) Pratt & Whitney PT-6 turbine engines. The Auxiliary Power Unit (APU) is an Alturdyne/Solar "Titan" gas turbine rated at 140 hp @ 3600 shaft rpm.

The air intake system for the four main propulsion engines and the APU was originally configured to pass all air through two Donaldson centrifugal separator type air cleaners. A portion of the cleaned air was diverted to the APU through about 12 feet of duct and a battery box to the plenum which (Rev. was fitted with a barrier filter (Donaldson P/N P14-2243, with paper filter medium) as a final protection for the APU turbine against particulate contamination.

The problem with the original system was that the barrier filter in (Rev. A) the plenum of the APU clogged after about 10 hours of operation.

Appendix A is a schematic of the Permakleen™ Air Cleaner System proposed by Pall Land and Marine (PLM) Corporation to provide a low maintenance, high efficiency air cleaner for the APU in place of the original barrier filter. It should also be noted that the air entering the Permakleeen® air cleaner does not first pass through the Donaldson inertial air cleaner.

The Permakleen™ Air Cleaner System was installed on LACV-30 craft No. 1 in December, 1985. Sampling and analysis of particulate contamination levels in the air stream at the inlet and outlet of the Permakleen™ unit was requested by the U.S. Army to demonstrate performance of the system in-service on LACV-30, craft No. 1, at Fort Story, Virginia. The sampling was conducted by Pall Scientific and Laboratory Services (SLS) Department on June 17, 1986.

Appendix B provides description of the sampling device used and the conditions of sampling.

Analytical Procedures

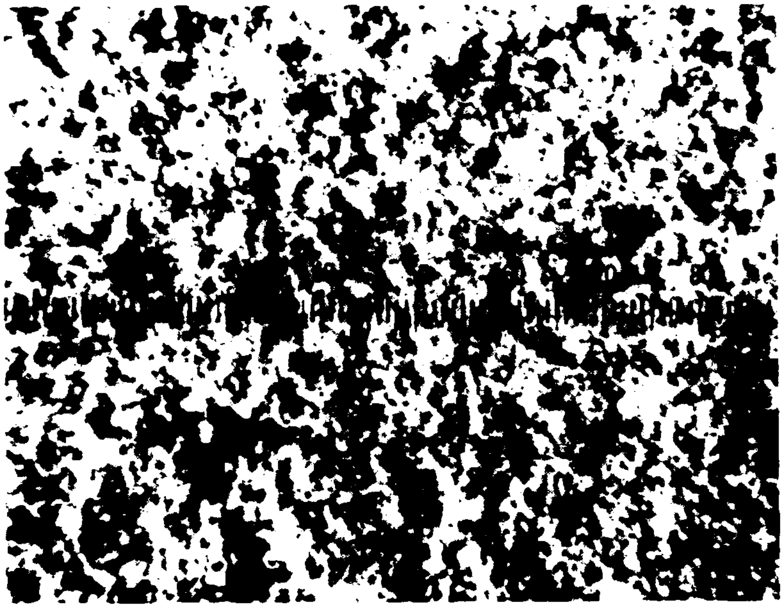
(See Appendix C)

Test Results

Contamination Levels In Impingers

The MIL-H-5606 in each impinger sampler (A, B, C and D) was particle counted. The results of particle counting are reported in the Table below as the total number of particles per impinger. Analytical membranes were prepared for photomicrographing representative contaminant particles in equal volumes of oil from sampling impingers A, B, C and D. These photomicrographs are shown in Figures I through IV. Figure V is a photomicrograph of original, clean MIL-H-5606 which was used to fill the impingers in preparation for the sampling.

FIGURE I



- IMPINGER A -
LAND RUN
- INLET -

This photomicrograph depicts contaminants filtered from 25 milliliters of sample oil from impinger A onto a 0.8μm (25 mm diameter) analysis membrane. The magnification is 100X. The scale is 13.6μm/div.

FIGURE II

- IMPINGER B -
LAND RUN
OUTLET OF PERMAKLEEN

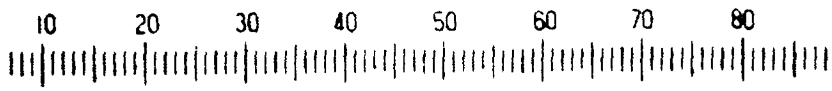
This photomicrograph depicts contaminants filtered from 25 milliliters of sample oil from impinger B onto a 0.8µm (25 mm diameter) analysis membrane. The magnification is 100X. The scale is 13.6µm/div.

FIGURE III

- IMPINGER C -
BEACH/OCEAN RUN
- INLET -

This photomicrograph depicts contaminants filtered from 25 milliliters of sample oil from impinger C onto a 0.8μm (25 mm diameter) analysis membrane. The magnification is 100X. The scale is 13.6μm/div.

FIGURE IV



- IMPINGER D -
BEACH/OCEAN RUN
OUTLET OF PERMAKLEEN

This photomicrograph depicts contaminants filtered from 25 milliliters of sample oil from impinger D onto a 0.8μm (25 mm diameter) analysis membrane. The magnification is 100X. The scale is 13.6μm/div.

FIGURE V

ORIGINAL - CLEAN
MIL-H-5606
USED TO CHARGE
IMPINGERS
A, B, C and D

This photomicrograph depicts contaminants filtered from 25 milliliters of original, clean MIL-H-5606 onto a 0.8μm (25 mm diameter) analysis membrane. The magnification is 100X. The scale is 13.6μm/div.

Scientific & Laboratory Services Dept.

Impingers	Particle Counts in Total Volume of MIL-H-5606 in Impinger					(Rev. A)	
Land Run	1 to 5μ	5 to 15μ	10 to 15μ	15 to 50μ	25 to 50μ	50 to 100μ	>100μ
A	31,424,923.0	6,074,155.3	5,260,238.3	575,180.8	265,780.0	20,043.1	2,123.5
B	242,203.0	8,567.0	728.0	1,898.0	676.0	182.0	13.0
Ocean/Beach Run							
C	177,992.5	39,550.0	12,670.0	7,420.0	2,432.5	1,155.0	297.5
D	82,841.0	10,200.0	1,496.0	3,111.0	2,023.0	663.0	136.0

Water Analysis

The total water contents of original condition MIL-H-5606, and samples of this oil in the used impingers from the beach/ocean run (i.e. impingers C and D) were determined using the Karl Fischer method.

Samples Oil (MIL-H-5606)	Total Water (ppm by weight)
-original oil	80
-oil from used impinger C	84
-oil from used impinger D	82

Total Sodium Analysis

Total sodium content was determined for original MIL-H-5606, original MIL-L-23699* and oil from each used impinger A, B, C and D.

*MIL-L-23699 - oil used to wet the barrier (mesh) in the Permakleen™ Air Cleaner System. (Rev. A)

Sample	Total Sodium (ppm)*
-original MIL-H-5606	0.50
-original MIL-L-23699	0.52
-MIL-H-5606 from used impinger A	0.49
-MIL-H-5606 from used impinger B	0.89

Sample	Total Sodium (ppm)*
-MIL-H-5606 from used impinger C	0.83
-MIL-H-5606 from used impinger D	0.67

*Note: Sodium content of sea water is approximately 14 mg/l. (ref. D. A. Livingstone, U.S. Geological Service. Prof. Pap. 440-G, 28 (1963) p. 41

Discussion

The results of particle counting analysis on the MIL-H-5606 in impinger samplers A and B (i.e. land run) show that the Permakleen™ Air Cleaner is functioning properly in the LACV-30. (Rev. A)

The table below provides calculated values of the number of particles per cubic foot of air at the inlet (i.e. impinger samples A) and outlet (i.e. impinger samples B) of the Permakleen™ system during the land run.

Impingers	Number of Particles Per Cubic Foot of Air						(Rev. A)
Land Run	>1µ	>5µ	>10µ	>15µ	>25µ	>50µ	>100µ
A	1,362,745.5	246,435.6	217,522.0	30,662.9	10,230.7	787.4	75.4
B	9,006.4	402.6	124.2	98.3	30.9	6.9	0.5

Based on the calculated values from the table above it is estimated that the Permakleen™ air cleaner was filtering more than 99.9 percent of solid particles larger than 10 microns. The numbers of particles larger than 10 microns in impinger B are within a range representative of background counts for these impingers. Consequently a 99.9% calculated filtration performance of the Permakleen™ system for particles larger than 10 microns in considered conservative.

The results of particle counting analysis on the MIL-H-5606 in used impingers C and D were complicated by coalescence of sea water droplets and subsequent evaporation of water to yield sea salt particles in the oil. Consequently, no conclusions regarding Permakleen™ filtration performance can be drawn from these samples (i.e. C and D). The results of analysis of total water content of the MIL-H-5606 in impingers C and D show that water content (82 to 84 ppm) was about the same as for original condition MIL-H-5606 (80 ppm). The low level of water in oil from impingers C and D is estimated to result from the evaporation of water in the impinger bowl because of the 17 inches (+) Hg vacuum in the bowl that maintains air flow through the impinger.

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The results of analysis of the oil samples for total sodium content show that levels were reduced about 2.65 times (adjusted for baseline contamination) from the common air inlet of the LACV-30 power system to the Permakleen™ system outlet. Based on the average level of sodium in sea water it is estimated that the equivalent of 0.2 milliliters of sea water was ingressing into the inlet stack per cubic foot of air taken in. At the (Rev. A) point of outlet from the Permakleen™ system the sea salt equivalent of sodium levels indicates that about 0.07 milliliters of sea water was contained in one cubic foot of air taken in by the APU turbine.

Conclusions and Recommendations

1. The results of testing show that the Permakleen™ Air Cleaner System in LACV-30 craft No. 1 is operating properly. The particle filtration performance of the Permakleen™ unit based on air sampling data is calculated to exceed, 99.9%.

2. The results of testing show that during the ocean run, inlet to outlet (of Permakleen™ system) sea salt levels were reduced about 2.6 times to a level equivalent to 0.07 milliliters sea water per cubic foot of air taken into the APU.

3. It is recommended that the Permakleen™ Air Cleaner System be implemented as the air intake filtration system for the APU in the LACV-30.

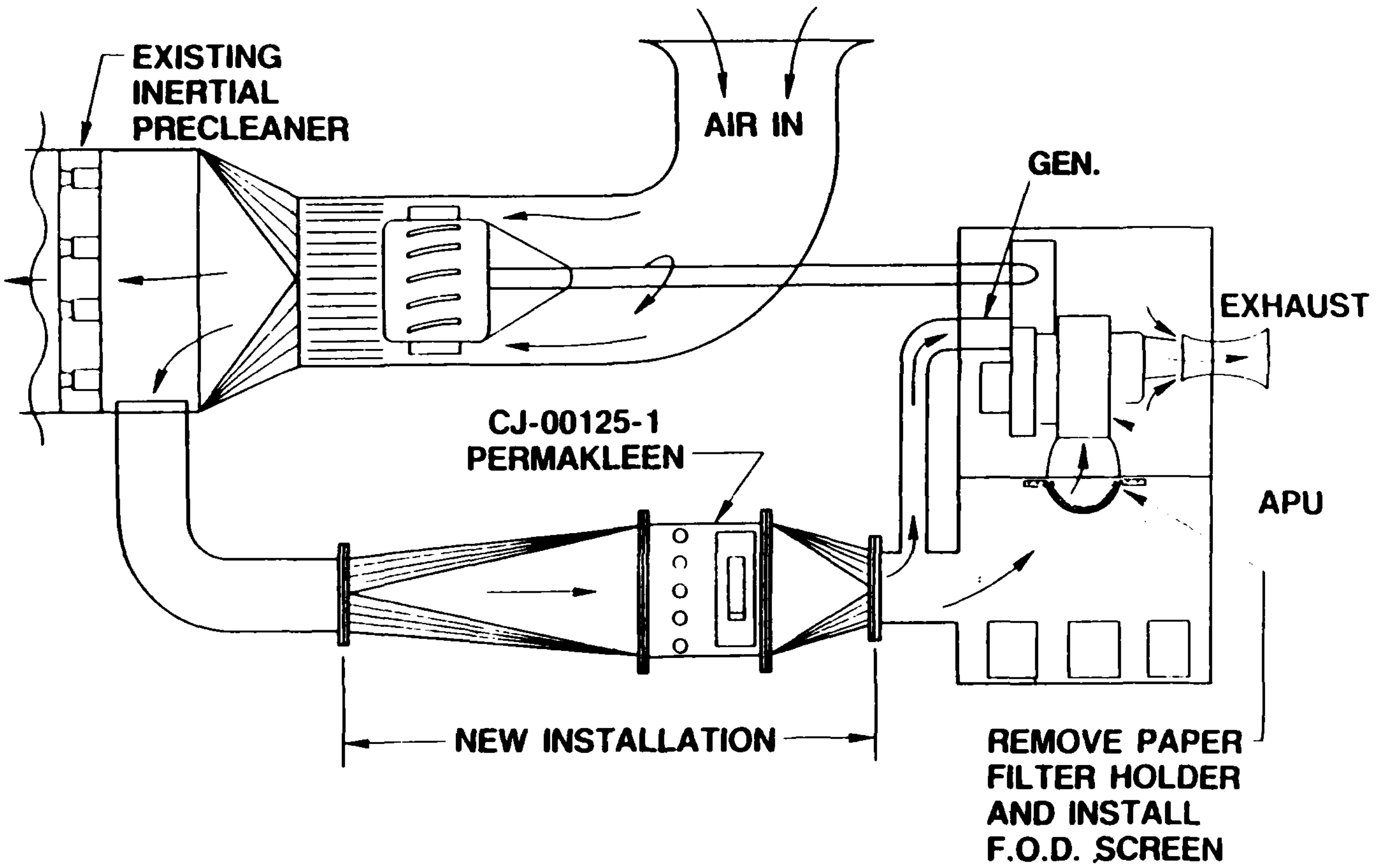
Daniel R. Uhr, Jr.

Daniel R. Uhr, Jr. Ph.D.
Staff Scientist
Pall Corporation
Pall Scientific and Laboratory
Services Department

DU:ds

Attachment(s)

PERMAKLEEN™ AIR CLEANER SYSTEM LACV-30 INSTALLATION



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APPENDIX A

APPENDIX B

LAVC-30 Permakleen™ Air Cleaner System
Air Sampling Test

Sampling Method

The air sampling method employs an impinger device (for example drawing see Appendix D) designed to draw air (by vacuum) from the duct into the impinger at the same air flow velocity as in the duct. This sampling process is commonly referred to as isokinetic sampling.

The air (along with particulate contamination) entering the impinger/sampler is channeled to a small ("critical") orifice where air velocity increases to about 850 ft/sec. The flow of air from the critical orifice exits to a bowl containing a liquid (initially very clean). The high velocity of particles in the air stream exiting the critical orifice assures impingement and capture of particles in the liquid. The liquid (in this case MIL-H-5606, hydraulic fluid) with captured contaminants was subsequently analyzed to determine levels of contaminants.

A description of the four impingers and conditions of operation used in this field sampling are provided below.

Air Sampling Impinger Code	Condition of Operation During Sampling
A	Placed inside the inlet stack during the land run (see Figure 1, Appendix B). The stack is a cylindrical duct with inside diameter at the level of sampling of about 46 inches. The impinger orifice has an inside diameter of 0.197 inches. The sizing of the impinger isokinetic sampling orifice assumes an air velocity in the duct of 34 ft/sec at the sampling point.
B	Placed at the outlet of the Permakleen™ unit (see Figure 2, Appendix B) during the land run. The point of sampling was within the bounds of the one inch wide, 8 inch diameter circular rim connecting the battery box and the duct work downstream of the Permakleen™ system. This impinger has an isokinetic sampling orifice of 0.125 inch diameter based on a calculated air flow velocity of 84 ft/sec in the duct at the point of sampling.

Note: Sampling impingers A and B were in operation during the land run (85% engine power) for a total of 65 minutes on 6/17/86.

Time	Model of Operation
10:05 am	Startup of engines
10:15 am	Takeoff
10:25 am	Light dust run
10:50 am	Heavy dust run (see Figure 3, Appendix B)
10:50 - 11:05 am	Set-down and shut-down on beach.

Figure 1 Main Air Intake Inlet Stack Location - Impingers A and B Air Sample Representative of Challenge to Permakleen Air Cleaner System

Figure 2 Battery Box - Outlet of Permakleen Air Cleaner System - Impingers C and D -

C	Placed inside the inlet stack during the beach and ocean run (see Figure 1, Appendix B). Other physical parameters were the same as for impinger A.
D	Placed at the outlet of the Permakleen™ unit (see Figure 2, Appendix B) during the beach and ocean run. Other physical parameters were the same as for impinger B.

Note: Sampling impingers C and D were in operation during the beach/ocean run (95.5% engine power) for a total of 41 minutes on 6/17/86:

Time	Mode of Operation
11:20 am	Startup of engines
11:35 am	Take-off over water (see Figure 4, Appendix B)
11:58 am	Set down on beach
12:01 pm	Shut down on beach

Figure 3 Moderate to Heavy Dust During Land Run - (i.e. Impingers A and B)

Figure 4 Water Mist During Ocean Run (i.e. Impingers C and D)

Appendix C

Analytical Procedures

All analytical procedures were performed in the facilities of the Scientific and Laboratory Services (SLS) Department of Pall Corporation in Glen Cove, New York.

1. Particle Counting

The procedure employed for counting contaminant particles in fluid samples parallels the industry-wide standard of S.A.E. ARP 598A, "The Determination of Particulate Contamination in Liquids by the Particle Count Method". A volume of sample fluid is drawn through a gridded, 0.8 micron, analysis membrane disc of 25mm diameter (2.8 cm^2 effective filtration area). Contaminant particles collected on the membrane surface are counted and sized using a Olmpus BH2U optical microscope with an oblique lighting source.

2. Photomicrographs

Color photomicrographs of the contaminant collected on a representative area of the analytical membrane surface are obtained at 100X magnification. A Vanox polarizing microscope with camera attachment is employed for this purpose.

3. Water Content Determination

Water in oil is measured by the Karl Fischer method, per ASTM Standard D-1744. This procedure measures the total content of water in a portion of the oil sample, both dissolved and free. A Photovolt Aqua Test II Karl Fischer Analyzer is employed for this procedure.

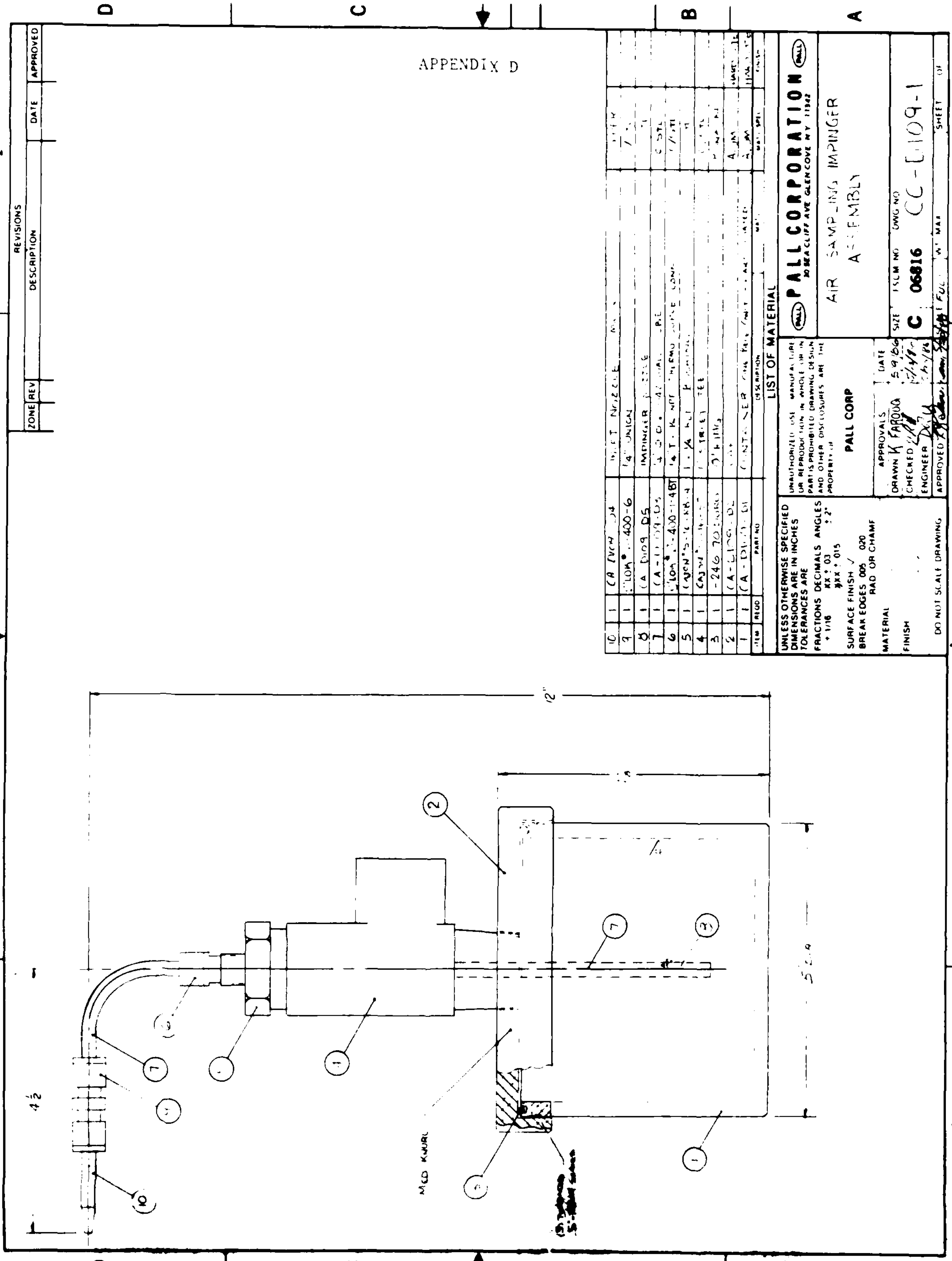
In order to determine the amount of free water present, ten (10) milliliters of the fluid sample are centrifuged at 3500 rpm for 15 minutes at 77°F (25°C). If more than 1% (10,000 ppm) of water is present, the water layer formed during centrifugation is compared to the oil layer, and the proportion reported as percent free water. If less than 1% water, Karl Fischer analysis is performed on the centrifuged oil layer to determine the amount of water dissolved in the oil. Free water is then determined as:

Free Water = Total Water - Dissolved Water

Total Sodium Analysis

Atomic absorption spectroscopy was employed to analyze quantitatively for sodium content. These tests were conducted on oil from the use impingers and base-line oil samples (i.e. MIL-H-5606 and MIL-L-23699) by Schwarzkopf Microanalytical Laboratory, Woodside, New York. This test report is on file in Pall/SLS.

APPENDIX D



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